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A FLORISTIC AND VEGETATION ANALYSIS OF A FRESHWATER TIDAL MARSH ON THE MERRIMACK RIVER, WEST NEWBURY, MASSACHUSETTS[1]

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ABSTRACT

Plant community structure and selected physical parameters influencing vegetational patterns were studied in a Merrimack River freshwater tidal marsh. A flora of 88 vascular plant species was documented. Special consideration was given to three species, *Scirpus fluviatilis, Bidens eatonii* and *Eriocaulon parkeri,* listed as rare for the Commonwealth of Massachusetts. Species abundance data were used to classify the vegetation into eight plant cover types using the computer program TWINSPAN.

Key Words: Freshwater tidal marsh, plant community, plant classification, TWINSPAN, rare plants, northeastern Massachusetts

INTRODUCTION

Freshwater tidal marshes develop in coastal rivers flooded daily by the incoming tides. The advancing salt front produces a salinity gradient from the ocean upstream to that portion of the river no longer under tidal influence. Coastal wetlands along this gradient are classified on a salinity-based system which defines a freshwater tidal marsh as one with an average annual salinity of less than 5‰ (parts per thousand) (Odum et al., 1984). These freshwater or near-freshwater conditions occur because the tidal influence exceeds the advance of the underlying salt wedge, causing a backflow of the overlying freshwater into the marshes. Freshwater tidal marshes occur where the salt front reaches its upstream limit in late summer when the river discharge is low.

The fluctuating physical conditions induced by changing tides make a freshwater tidal marsh a unique environment for vegetation. Several studies have been conducted describing the distribution and abundance of intertidal vascular plants from these marshes (Nichols, 1920; Fassett, 1928; Ferren and Schuyler, 1980; Metzler and Rosza, 1982; Odum et al., 1984; Odum, 1988). Fresh-

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water tidal marshes have been described by several authors as transition zones between fresh and salt water habitats (Philipp and Brown, 1965; Anderson et al., 1968; Ferren, 1976; Garofalo, 1980; Haramis and Carter, 1983), and species diversity across this transition zone typically decreases as salinity increases (Odum, 1988). A number of unusual species restricted to estuaries, as well as rare plants, have been documented from this type of marsh (Fernald, 1903; Fassett, 1925a, 1925b, 1928; Mathieson and Fralick, 1973; Ferren and Schuyler, 1980; Crow, 1982; Sorrie, 1987; Barrett, 1989 MS thesis, Univ. of Conn., Storrs, CT).

The forces of strong tidal and river currents and ice floes have a strong influence on the morphology and vegetation of a freshwater tidal marsh. Marsh soil is directly affected by sediment accretion and erosion as well as by other factors (Ahnert, 1960; Dionne, 1968, 1969, 1974; Garofalo, 1980; Serodes and Troude, 1984).

Zonal patterns of vegetation may develop in response to environmental gradients in freshwater tidal marshes. Some studies have correlated plant community structure and productivity with certain environmental parameters such as elevation of the marsh, tidal submergence, salinity, soil texture, soil organic material and soil redox potential (Disraeli and Fonda, 1979; Hutchinson, 1982; Ewing, 1983, 1986).

Freshwater tidal marshes occur on both coasts in North America, but the Pacific coast marshes are not as extensive as those along the Atlantic (Disraeli and Fonda, 1979). In Massachusetts, two river systems support sizable freshwater tidal marshes, the North River (Plymouth Co.) and the Merrimack River (Essex Co.). The Merrimack River arises in the White Mountains of New Hampshire and empties into the ocean near Newburyport, Massachusetts, where the Merrimack forms a wide estuary at its confluence with the Parker River, north of Plum Island.

This study of the Merrimack River freshwater tidal marsh was initiated with the following objectives: 1) to conduct a complete floristic survey of the area; 2) to collect species abundance data and classify the vegetation into cover types; 3) to document populations of plants listed as rare for the Commonwealth of Massachusetts; 4) to describe the marsh habitat, including plant cover types, tidal fluctuation, free water salinity, and soil organic matter content; and 5) to assess the relationship between plant community structure and selected environmental characteristics.

Site Description

The study site occurs along a segment of the Merrimack River in the Town of West Newbury, Essex County, Massachusetts, approximately nine miles from the ocean (42°49′N Lat., 71°57′W Long.). The study area begins at the Indian River and extends east for 1¼ miles to the Artichoke River. Three marsh areas occur between these two tributaries, separated by sections of rocky shoreline (Figure 1). The average area of each marsh is approximately 400 × 150 meters.

Because the high tide zone borders a sloping forested riverbank, the Merrimack River marsh contains only two small areas where high marsh habitat has developed. These areas occur as slightly elevated islands near the mouths of the Artichoke and Indian Rivers, and appear to be sections of land that have become isolated by a backwash of these tributaries from tidal flooding.

MATERIALS AND METHODS

Environmental Measurements

Tidal Amplitude

Tidal amplitude was recorded during September and October of 1989 using a Stevens Model F Recorder. Since the Merrimack River is used extensively for boating, it was not advisable to place the recorder in the river channel at the low tide level. A reference location was chosen for the recorder platform in Area #3 (see Figure 1) at the edge of the vegetation nearest the river channel at low tide. Therefore, data do not include full low tide range of the river, but they do measure tidal amplitude and duration of flooding for all vegetation zones in the marsh.

Surface elevation of this marsh area relative to the recorder platform was measured using a line level and meter rod. The longest transect in the center of Area 3 was chosen to represent the average elevation of sampled areas.

Salinity

Free-water salinity measurements were taken in the spring and fall of 1989 using a portable Y-S-I model 33 salinometer. Mea-

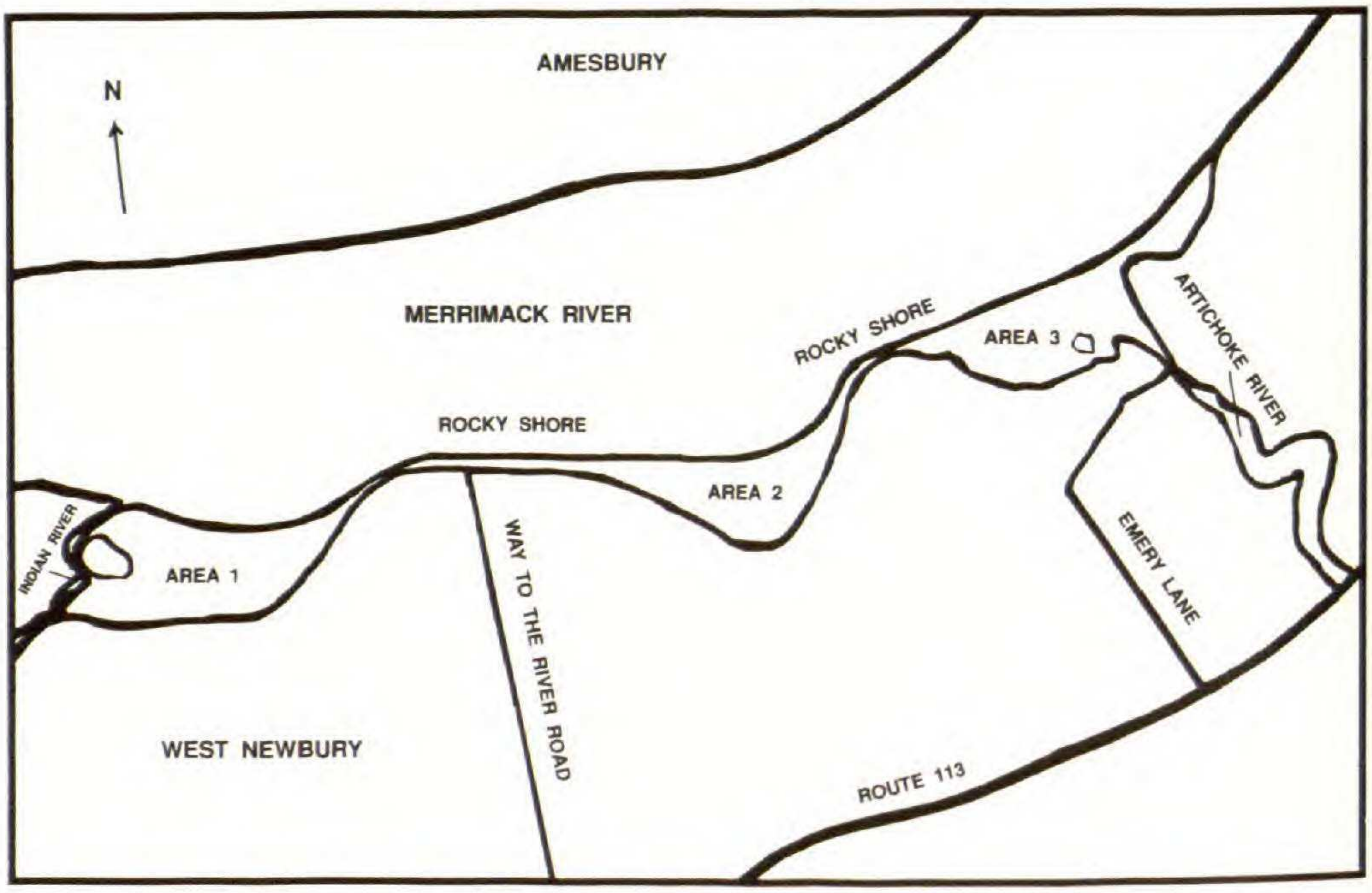

Figure 1. Map of study site.

surements were recorded during the high tide cycle at several sampling stations in the marsh and at various depths within the water column. Temperature and conductivity were also recorded.

Soil Organic Matter Content

Soil samples were collected in June 1989 from Area #1 for organic matter content determination. Three replicates were collected at 5 cm and 10 cm depths at four intervals along a transect corresponding with different plant cover types. Samples were oven-dried at 80°C for 24 hours and ashed in a muffle furnace at 475°C for 24 hours. Percentages of water and organic matter content of the soil were calculated from these weights.

Vegetation Analysis

Vegetation data were collected in August and September of 1988 and 1989. These months were chosen for vegetation sampling because combined patterns of all species produce a peak community biomass in August (Doumlele, 1981). Sampling was done using the stratified random sampling method (Mueller-Dombois and Ellenberg, 1974). Three transects were established in each of the three marsh areas, and 23 transects were established along the rocky shore areas at 50-meter intervals for a total of 32 transects. Each transect ran perpendicular to the edge of the river and extended from the beginning of the rooted vegetation exposed at low tide to the upper edge of the high tide zone. A quadrat size of $\frac{1}{2} \times \frac{1}{2}$ meter was used in a total of 323 sample plots. One quadrat was randomly located within each five meter segment of marsh transect and three meter segment of rocky shore transect. A shorter random sampling segment was chosen for the rocky shore transects because the length of each of these transects was relatively short, and elevational gradient was steeper.

Percent cover was recorded to estimate the abundance of 30 vascular plant species occurring in the quadrats. Cover was defined as the projection of the crown or shoot area of a species to the ground surface expressed as a percent of the quadrat area (Mueller-Dombois and Ellenberg, 1974).

Data were analyzed using TWINSPAN (Two-Way Indicator Species Analysis), a Fortran program designed to construct a classification of samples that are then used to classify species according to their ecological preference (Hill, 1979). The program groups quadrat samples and species by repeated dichotomies. Three ordinations are used in the dichotomy determination: 1) primary ordination, which uses a reciprocal averaging method; 2) refined ordination, which uses differential species; and 3) indicator ordination, which uses indicator species (Hill, 1979).

Floristics

An inventory of the vascular plants of the Merrimack River freshwater tidal marsh was undertaken during the 1988 and 1989 field seasons. Voucher specimens were collected and deposited at NHA. Documentation of three rare plants, *Bidens eatonii, Eriocaulon parkeri* and *Scirpus fluviatilis* and their habitat description were also included in this study.

Identifications were based on *Aquatic and Wetland Plants of Northeastern North America* (Crow and Hellquist, in press), *A Manual of Vascular Plants of Northeastern United States and Adjacent Canada* (Gleason and Cronquist, 1963) and *Gray's Manual of Botany* (Fernald, 1950). Additional references included: *New Britton and Brown Illustrated Flora* (Gleason, 1952) and

Aquatic Vascular Plants of New England Parts 1–8 (Hellquist and Crow, 1980, 1981, 1982, 1984; Crow and Hellquist, 1981, 1982, 1983, 1985).

RESULTS AND DISCUSSION

Environmental Measurements

Tidal Amplitude

The total range of tidal amplitude measured for 76 cycles was 0–150 cm, with high tides ranging from 82–150 cm; mean high tide calculated from all recorded tides was 115 cm.

The elevation of the marsh surface was 40 cm, as measured from the base of the tide gauge to approximately mean high tide along a 147 meter transect. A rise in elevation of 15 cm occurred along the first 25 m nearest the river; the remaining 25 cm of rise in elevation occurred over the last 122 m of the marsh. This gradual slope across the marsh platform is typical of freshwater tidal marshes, and has been described by several authors (Metzler and Rosza, 1982; Ewing, 1983; Odum et al., 1984; Mitsch and Gosselink, 1986).

Many sections of the high tide zone end in an erosional step that abuts a sloping river bank. This step accounts for much of the difference in high tide water levels and the measured slope of the marsh surface. A similar geomorphology was reported by Hutchinson (1982) in the Fraser River tidal marshes of British Columbia. Other sections end in a forested slope which was beyond the scope of this study.

Duration of inundation in the Merrimack River marsh at the elevation of the tide gauge was approximately 16 hours per day during two tide cycles. Mean high tide data (115 cm) were used for this determination. Water level plotted against duration of inundation at the plant/soil interface shows submergence time for different elevations across the marsh platform (Figure 2). Cover types such as *Scirpus pungens* and *Spartina alterniflora* that occur at the lower edge of the vegetation zone are partially submerged for 16 hours a day and fully submerged for a portion of that time, depending on their height and elevation. Decreased levels of light and gas exchange, characteristic of a submerged

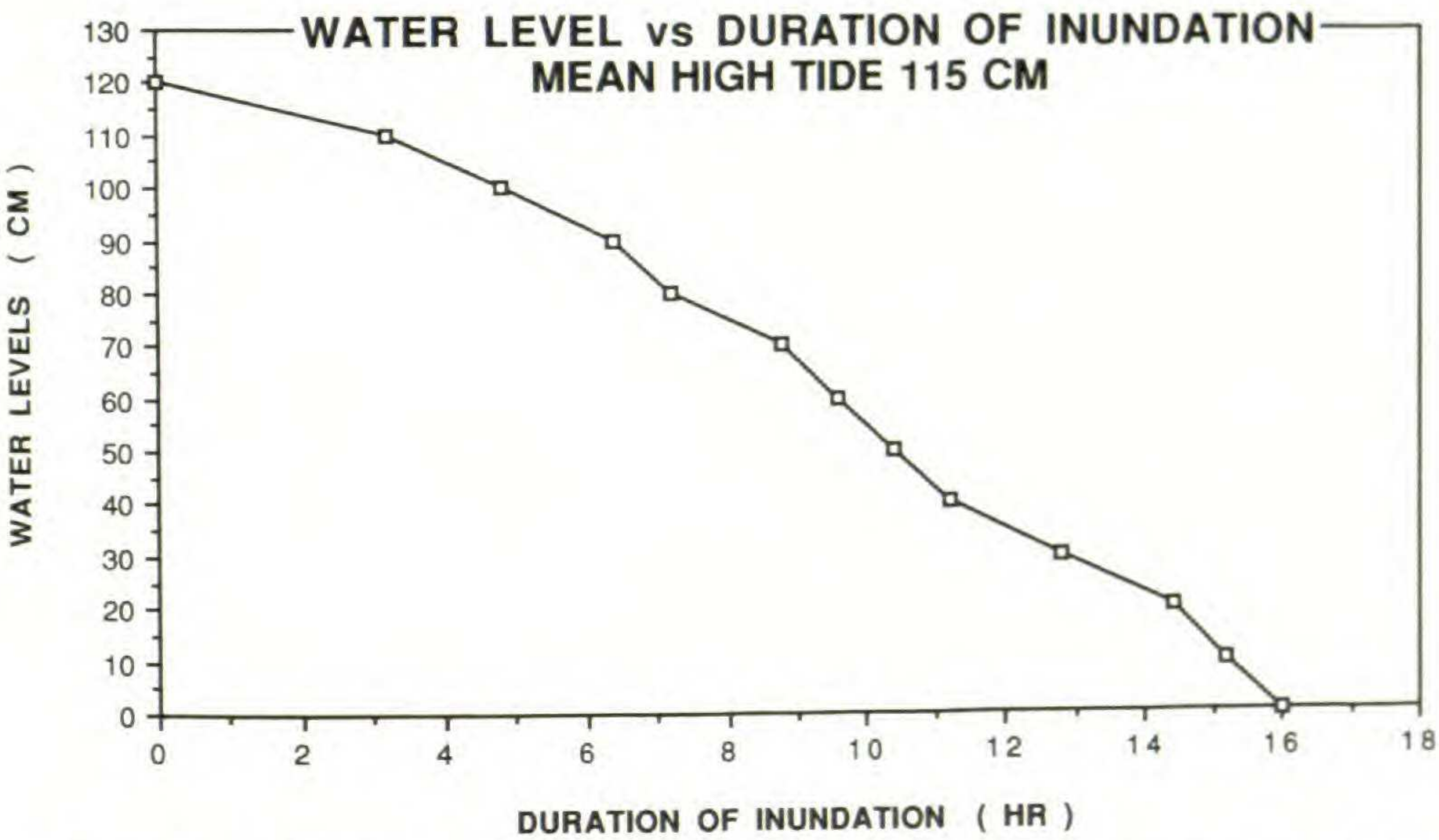

Figure 2. Water level versus duration of inundation at the plant/soil interface for two tide cycles taken from 115 cm mean high tide data.

habitat, make this environment suitable for only a select number of emergent plants.

The mid-marsh and backmarsh portions of the surface below 40 cm elevation are flooded for at least 11 hours per day at the plant/soil interface (Figure 2). Cover types occurring in this area include *Scirpus tabernaemontanii*-type, *Acorus calamus*-type and *Zizania aquatica*-type. Although tide gradient front-to-back in the marsh seems relatively small, it is probably a significant factor in controlling distribution of these cover types.

In a study based on a linear regression analysis of selected physical parameters in the Nooksack River delta in Bellingham Bay, Washington, Disraeli and Fonda (1979) reported that the most important environmental factor affecting plant distribution was elevation above mean low water. They further added that this factor controlled frequency and duration of submergence and indirectly affected all other factors. Using analysis of variance to assess which physical factors governed plant species distribution, Hutchinson (1982) reported that "species distribution is clearly controlled by the elevation of the marsh platform and the associated tidal regime." Several other authors report similar conclusions (Johnson and York, 1915; Nichols, 1920; Philipp and Brown, 1965; Metzler and Rosza, 1982; Ewing, 1983; Keddy, 1983; Chabreck, 1988).

Table 1. Water analysis data recorded from eight stations at high tide in the Merrimack River marsh study site.

Date 1989	Average Salinity (‰)	Salinity Range (‰)	Average Conductivity (μmho)	Average Temperature (°C)	(°F)
May 20	0.0	–	–	20	68
June 18	0.0	–	106	20	68
Sept 16	1.4	0.8–4.8	1742	21	70

Salinity

Except for one sampling period in the fall, all samples showed 0‰ salinity. The only detectable salinity occurred in mid-September, when it averaged 1.4‰ in the water column with a range of 0.8 to 4.8‰ (Table 1). These readings classify the study site as a freshwater tidal marsh, since by definition, this type of marsh must be tidal and have an average annual salinity of less than 5‰ (Odum et al., 1984).

The seasonal salinity pattern reported here supports previous data recorded from this area of the Merrimack River. Jerome et al. (1965) reported that during an eight month survey only one salinity measurement of 5.0‰ was recorded in October from the Artichoke River Station in the Merrimack River.

In another study conducted on the Merrimack River, Miller et al. (1971) indicated that the limit of the salt intrusion at high tide varied from 4.3 to 10.9 miles from the mouth depending upon the season. They found gross fluctuations in salinity both daily and seasonally in this section of the river. Disraeli and Fonda (1979) also found a similar salinity pattern in the Nooksack River in Bellingham Bay, Washington, with a maximum salinity of 5.19‰ in October.

Soil Organic Matter Content

Soil organic matter and water content measurements may help to determine the nature of the marsh soil, which varies considerably among river systems and marsh types (Chabreck, 1988). Soil samples for these determinations were collected; organic matter analysis showed a gradient from 1.49 percent in the low tide zone to 19.81 percent in the backmarsh (Table 2). This type of

Table 2. Soil analysis data taken at four intervals and at two depths along a transect in Area 1. These data represent an average of three samples.

Distance from Vegetation Edge (Low Tide Zone) (Meters)	% Organic Content of Soil		% Water Content of Soil	
	Depth		Depth	
	5 cm	10 cm	5 cm	10 cm
5	1.64	1.49	26.73	20.95
25	2.46	2.57	30.89	25.78
75	6.85	4.29	43.66	33.17
125	19.81	17.86	68.09	64.41

gradient is predictable since the action of the tides sweeps away the organic debris from the low- and mid-marsh areas and deposits it in the backmarsh. Whigham and Simpson (1975) also found that soil organic concentration increased on a gradient from actively flooded stream banks to less actively flooded areas in the Hamilton Marshes in New Jersey.

The soil in the Merrimack River foremarsh is mainly gray clay mixed with some silt and sand. Since the organic content of this soil is less than 15 percent, it may be classified as a mineral soil (Dachnowski-Stokes, 1940). By contrast, the backmarsh substrate can be classified as muck since it contains an organic content in the 15 to 50 percent range. Large deposits of silt are also an important component of the mid- and backmarsh soils.

Although a great deal of between- and within-site variability exists, average organic content taken from a series of samples from the east coast of North America ranged from 20 to 70 percent, with a mean of 35 percent (Odum, 1988). Along the Delaware River in New Jersey, Whigham and Simpson (1975) showed a range of 14 to 40 percent organic matter. Relative to these findings, the Merrimack River marsh has a low organic content. These results may be due to the absence of "high marsh" areas relative to other freshwater tidal marshes. High marsh areas are elevated sections of the marsh that are less exposed to tidal currents. They are usually flooded only during seasonal high tides and, for a variety of reasons, poorly drained. These conditions facilitate the build-up of organic matter in the soil. The low measurement may also be a result of insufficient sampling.

Water content in the Merrimack River marsh tends to parallel organic content. A front-to-back marsh gradient exists with respect to soil water content, with a range of 27 percent to 68 percent respectively (Table 2). Both Disraeli and Fonda (1979) and Hutchinson (1982) found that soil water content was highest in the high- and mid-marsh areas at low tide. They attribute these findings to differences in soil texture and drainage patterns from front to backmarsh. There is usually a higher proportion of fine sand in low marsh substrate, resulting in a more rapid drainage of these soils during ebb tide.

In contrast, the backmarsh contains a more organic matter and drainage patterns are poorer. In the Merrimack River marsh, backmarsh is typically waterlogged due to gradual surface slope and dense network of rhizomes of *Acorus calamus* in the mid-marsh section.

Differences in percent organic and water content between 5 cm and 10 cm depths are shown in Table 2. In all cases, percent organic matter and water content decreased with depth. The dynamics of an intertidal marsh prevent long-term accumulation of organic matter, and consequently less is found at greater depths.

Plant Cover Types

The vegetation was classified using TWINSPAN into eight plant cover types (Figure 3). Four hierarchical divisions were used to cluster the 323 quadrats and 30 plant species into these eight groups.

In the first dichotomy, TWINSPAN separated the 66 quadrats corresponding to the rocky shore sites from the 257 marsh quadrats. Five plant cover types were further delineated from the analysis of marsh vegetation data and were named according to their dominant vascular plant species. The *Spartina alterniflora* cover type is the first to be defined on the second divisional level. The *Scirpus tabernaemontanii* and *Acorus calamus* cover types are split on the third divisional level, but they are not completely defined until they are separated from the *Sagittaria graminea* and *Zizania aquatica* cover types on the fourth divisional level. Divisions with less than five quadrats are not considered sufficiently distinct to designate as a cover type.

In the rocky shore areas, three plant cover types are recognized at three divisional levels, *Spartina pectinata* cover type at level two and *Scirpus pungens* and *Amaranthus cannabinus* cover types at level three (Figure 3). Fewer quadrats were sampled in the

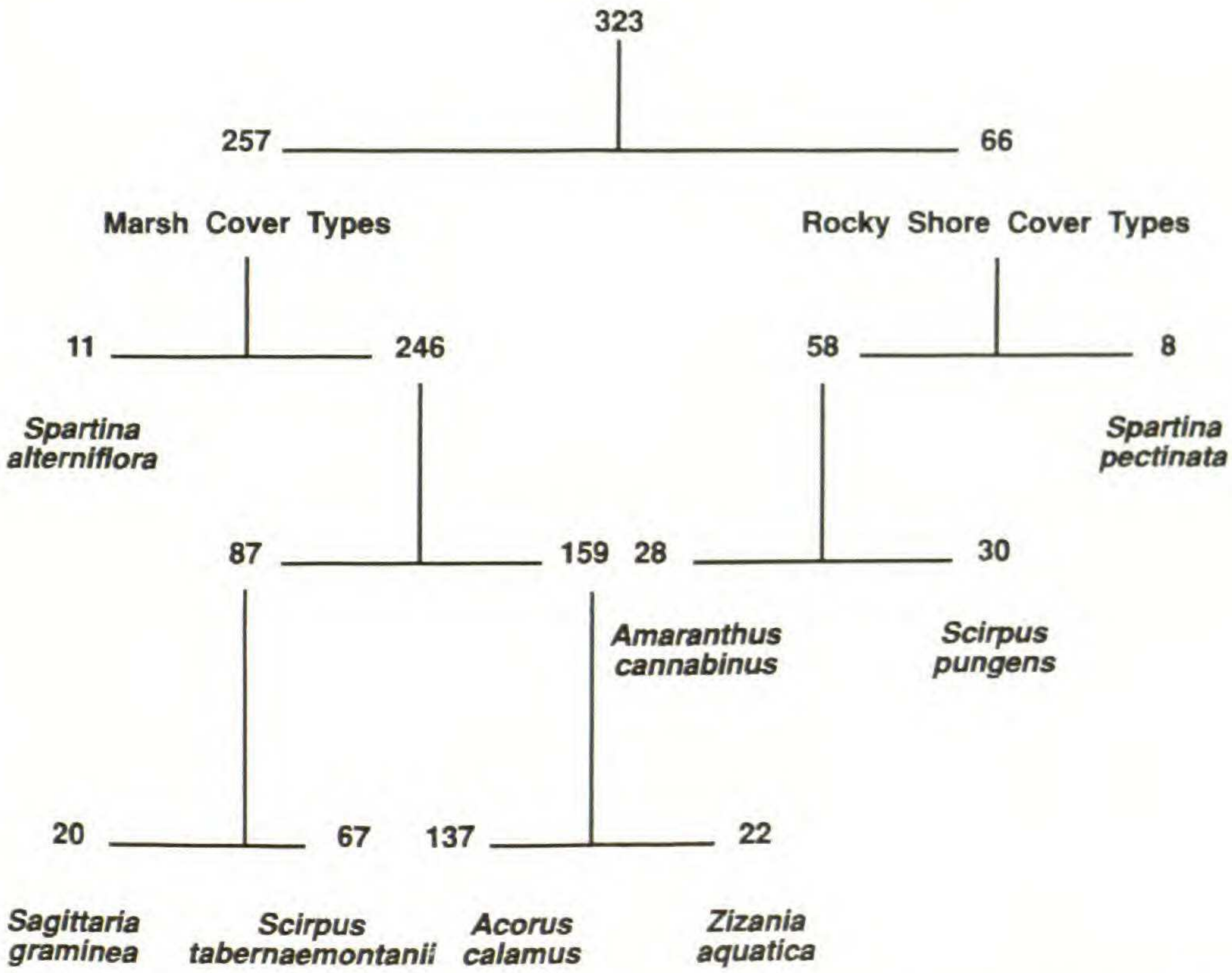

Figure 3. TWINSPAN analysis showing the eight plant cover types classified at four hierarchical levels.

rocky shore sites since these areas comprised a considerably smaller portion of the study site than the three large marshes. Because of the comparatively small number of samples and sparseness of vegetation, it is not meaningful to describe cover types beyond the third divisional level in these areas.

The two habitats identified by the first dichotomy exhibit differences in topography, substrate and vegetational patterns. The three marsh areas are broad with sections of dense vegetation, a relatively flat surface and a silty-clay organic substrate. Borders of these marshes adjacent to the river channel consist of extensive mud flats that are exposed at low tide and are devoid of vegetation throughout the year. The overriding impression of the vegetational pattern in these marsh areas is one of zonation due to broad bands of dominant species, although the borders may be highly irregular (Figure 4).

In contrast, rocky shoreline areas which occur between marshes are characterized by more steeply sloping surfaces, stony-sandy substrates and mosaic patterns of sparse vegetation (Figure 5).

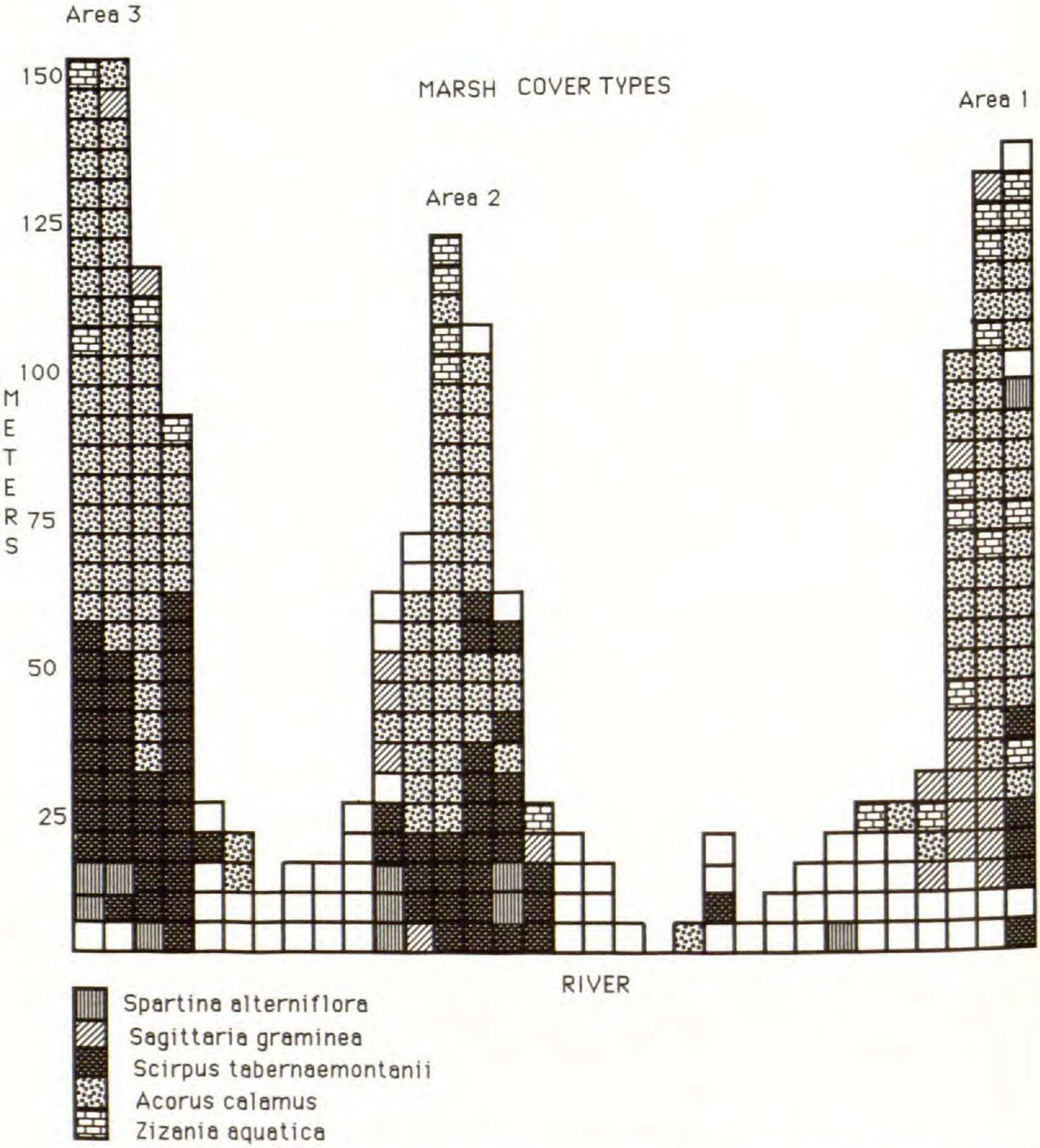

Figure 4. The distribution of marsh cover types in three marsh areas. Each square represents a ½ × ½ meter quadrat within a 5-meter segment of transect. The transects are depicted vertically and are separated horizontally by distances ranging from 50–150 meters.

These shore areas are more exposed to erosive currents, ice scouring, and wind than are the marshes, and this high degree of disturbance may be a contributing factor to the patchy distribution of vegetation. While each cover type throughout the marsh is characterized by one or more dominant plants, some species such as *Polygonum punctatum* and *Sagittaria latifolia* do not have a strong affinity for any particular area within the intertidal zone, and are found in several different cover types.

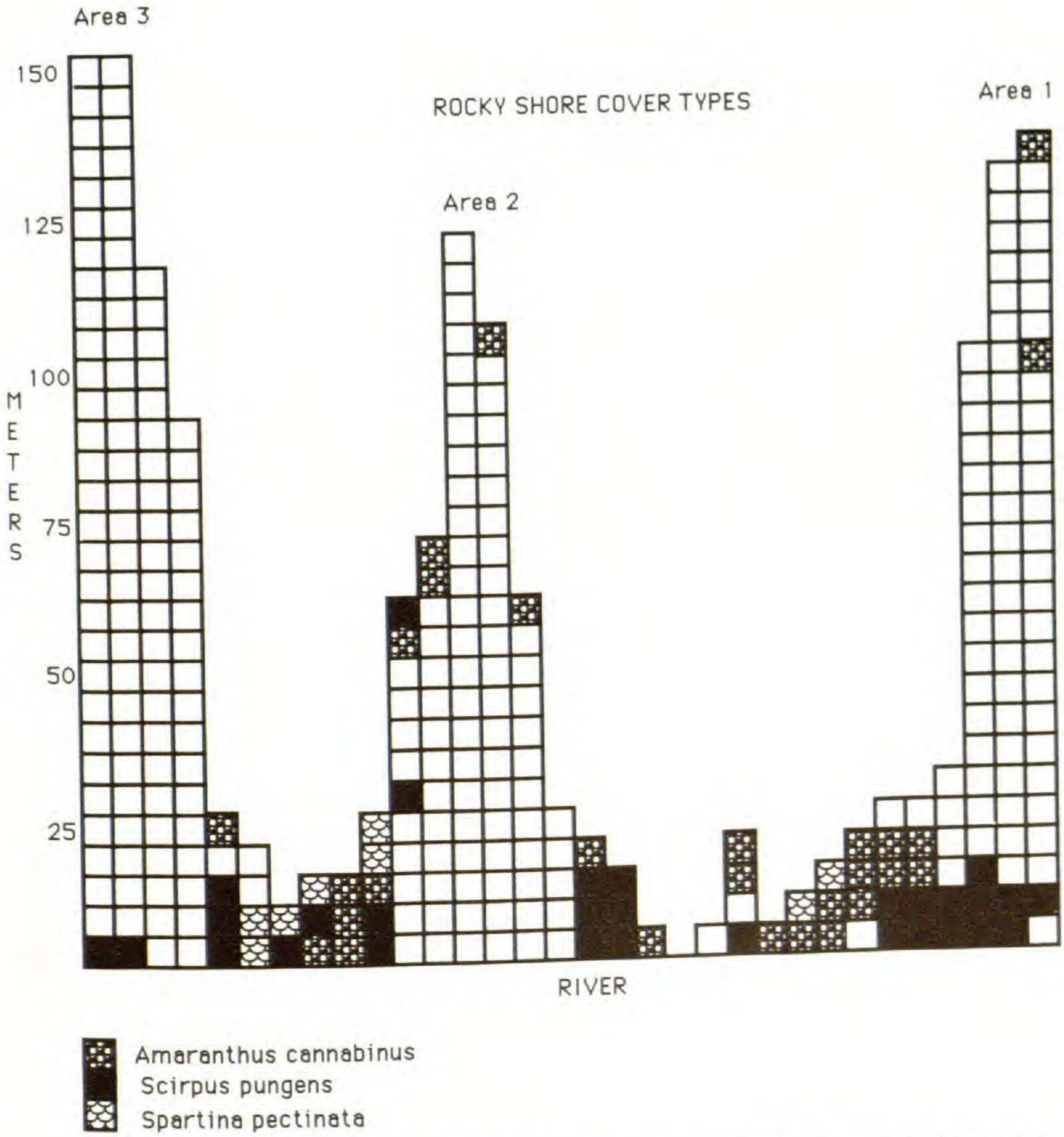

Figure 5. The distribution of rocky shore cover types. Each square represents a ½ × ½ meter quadrat within a 3-meter segment of transect. The transects are depicted vertically and are separated horizontally by distances ranging from 50–150 meters.

MARSH PLANT COVER TYPES

Spartina alterniflora Cover Type

The *Spartina alterniflora* cover type is one of the less common of the eight plant associations described. The community can be characterized by three species, but *Spartina alterniflora* dominates, with a mean cover of 26 percent (Table 3).

Spartina alterniflora is typically found in more saline habitats, but since freshwater tidal marshes are transitional to salt marshes,

Table 3. Mean percent cover for 25 species in 8 plant cover types. 1 = *Spartina alterniflora*. 2 = *Sagittaria graminea*. 3 = *Scirpus tabernaemontanii*. 4 = *Acorus calamus*. 5 = *Zizania aquatica*. 6 = *Spartina pectinata*. 7 = *Amaranthus cannabinus*. 8 = *Scirpus pungens*. (Species with <1% cover are omitted.)

Cover Types	1	2	3	4	5	6	7	8
Number of Quadrats	11	20	67	137	22	8	28	30
Sagittaria graminea	—	38	2	2	4	—	1	2
Ludwigia palustris	—	—	—	—	1	—	—	—
Elodea nuttallii	1	—	3	1	—	—	—	—
Zizania aquatica	—	7	—	—	42	—	1	—
Spartina alterniflora	26	—	—	—	—	—	—	—
Scirpus tabernaemontanii	9	9	32	1	—	—	—	—
Elatine americana	—	—	5	—	—	—	—	—
Sagittaria latifolia	—	2	2	10	1	—	1	—
Acorus calamus	—	1	13	55	3	—	1	—
Bidens cernua	—	3	—	3	13	—	—	—
Pontederia cordata	—	—	—	6	3	—	—	—
Scirpus fluviatilis	—	—	—	3	2	—	—	—
Polygonum punctatum	—	1	—	2	3	4	2	—
Bidens sp.	—	—	—	2	13	—	2	—
Sium suave	—	—	1	5	3	14	9	—
Lythrum salicaria	—	—	—	—	—	3	—	—
Spartina pectinata	—	—	—	—	—	39	—	—
Lycopus americanus	—	—	—	—	—	1	—	—
Aster novi-belgii	—	—	—	—	—	9	—	—
Amaranthus cannabinus	—	—	—	—	—	3	16	—
Pilea pumila	—	—	—	—	—	—	1	—
Juncus acuminatus	—	—	—	—	—	—	1	—
Eleocharis smallii	—	1	—	—	1	—	1	—
Mimulus ringens	—	—	—	—	—	—	1	—
Scirpus pungens	—	2	—	—	—	5	6	17

this saltwater cordgrass may occasionally be found upstream under nearly freshwater conditions (Ferren, 1976). In the Merrimack River marsh, *Spartina alterniflora* is most abundant at the seaward edge of the study site in the low tide zone. A dense network of rhizomes and roots makes it very resistant to erosive forces, allowing it to colonize unstable areas (Garofalo, 1980). Although *Scirpus tabernaemontanii* grows with these clumps of cordgrass, it is usually found in the midmarsh areas where it forms nearly homogenous zones. The other components of this cover type, such as *Elodea nuttallii* and *Elatine americana*, are submerged aquatics that are tolerant of the alternately flooded and exposed mud flats in the low tide zone.

Sagittaria graminea Cover Type

The *Sagittaria graminea* cover type (Table 3) extends from exposed mud flats in the low tide zone to fringes of the backmarsh. The dominant species, *Sagittaria graminea*, is typically associated with *Scirpus pungens* and *Scirpus tabernaemontanii* in the low- to mid-marsh areas, and with *Zizania aquatica, Sagittaria latifolia, Bidens cernua* and *Polygonum punctatum* in the backmarsh. This distribution occurs primarily because *Sagittaria graminea* has adapted to a wide range of environmental conditions.

When *Sagittaria graminea* occurs in the low tide zone where it is submerged throughout most of the day, the plants form colonies of sterile rosettes with linear-lanceolate phyllodia. In the backmarsh, however, the plants are only occasionally submerged, and it is under these conditions that they develop larger, broader leaf blades and occasionally flowers. Ferren and Schuyler (1980) reported that plants of the upper intertidal zone had several verticils on their inflorescence axes, while those growing in the lower intertidal zone had one to rarely three verticils of flowers. Flowering specimens of *S. graminea* in the Merrimack River marsh usually had one or two verticils. *Sagittaria graminea* rarely produces achenes in New England (Hellquist and Crow, 1981), and none was observed in this study.

Scirpus tabernaemontanii Cover Type

This cover type is characterized by the soft-stemmed bulrush, *Scirpus tabernaemontanii* (Table 3), which forms a broad band from the lower edge of the vegetation zone to the midmarsh area. Other rhizomatous perennials such as *Acorus calamus* and *Sagittaria latifolia* are included in this association, but they rarely inhabit the low tide zone. The submerged aquatics, *Elodea nuttallii* and *Elatine americana*, grow intermixed with these emergents and form small patches on the surface of the mud in frequently inundated areas. This cover type is found mainly at sites with a silty clay substrate, and its borders are abrupt when the substrate changes to sand and gravel near the rocky shore areas.

The dominant species in this cover type, *Scirpus tabernaemontanii*, is a rapidly growing perennial which reaches heights of three meters or more. Stored nutrients in the rhizomes may allow the early and rapid development of plants of this species that obtain their peak biomass in early June along with *Acorus calamus* (Whigham et al., 1978). The height, abundance and early emergence of *S. tabernaemontanii* make it one of the predominant species of the entire freshwater tidal marsh.

Acorus calamus Cover Type

The *Acorus calamus* cover type spans by far the largest area of the Merrimack River marsh, extending from midmarsh to the border of the backmarsh in some sections. The TWINSPAN analysis clustered 137 quadrats and 11 species in separating out this community. Because this cover type encompasses such a large area and tidal range, its species diversity is relatively high, despite the overriding dominance of *A. calamus* (Table 3). Dense rhizomatous colonies of this plant dominate the midmarsh section and may extend up to sixty meters along certain transects. Apparently this species reproduces almost exclusively by rhizomes since it is a common plant in these marshes and has not been documented in several seed bank surveys (Leck and Graveline, 1979; Leck and Simpson, 1987; Simpson et al., 1983).

The backmarsh elements of this cover type are characterized by the broad-leaved emergents *Sagittaria latifolia, Pontederia cordata,* and occasionally *Peltandra virginica.* These species are most abundant in wet organic mucky substrates. Although *Sagittaria latifolia* also occurs in the midmarsh, plants are larger and flower more frequently in the backmarsh. *Scirpus fluviatilis* is another important member of this backmarsh cover type, and is discussed in the rare plant section.

The annual plant component of this cover type is found most often intermixed with *Acorus calamus.* The dense and partially exposed system of rhizomes of *A. calamus* gives the marsh an irregular surface which provides a microhabitat for seeds of annuals such as *Sium suave, Bidens cernua, B. connata,* and *B. eatonii.* In winter, clumps of these rhizomes are uplifted along with ice blocks and deposited downstream along the shoreline (Hardwick-Witman, 1984 MS thesis, Univ. of New Hampshire, Durham, NH). Observations over the two year-study period, however, revealed that erosive forces prevented establishment of these clumps in the low tide zone in the Merrimack River marsh.

Zizania aquatica Cover Type

This cover type consists of several perennial backmarsh emergents, but it is dominated by the late-summer annuals *Zizania aquatica* and *Bidens* spp. *Zizania aquatica* requires soft mud and slowly circulating water typical of a backmarsh habitat (Odum et al., 1984), but it may also be found in small depressions throughout the midmarsh (Figure 4). Other associated species include *Sagittaria graminea, Pontederia cordata, Polygonum punctatum, Sium suave, Ludwigia palustris* and *Eleocharis smallii* (Table 3).

The late maturity of *Zizania aquatica* and *Bidens* makes this cover type the last to appear in the seasonal succession of marsh vegetation. Root growth predominates during early development of *Z. aquatica,* but later in the season, shoot growth may be up to 6.5 cm per day (Good and Good, 1975); this shallow-rooted grass can reach heights of 4 m. Lodging of large stands of this plant has been observed in the study site due to waves from storms and heavy boat activity on the river.

ROCKY SHORE COVER TYPES

Spartina pectinata Cover Type

This freshwater cordgrass cover type represents a small portion of the rocky shore vegetation. Its definition by TWINSPAN involved only eight quadrats. *Spartina pectinata,* the dominant species in this cover type, occurs most often along back borders of rocky shore areas in sandy substrate with other species such as, *Aster novi-belgii* and *Lythrum salicaria.* It also grows mixed with annuals that are common there (Table 3). The two major perennials in this cover type, *Spartina pectinata* and *Aster novi-belgii,* have rhizomatous root systems that enable them to withstand the adverse conditions characteristic of this section of the Merrimack River marsh. This band of shoreline is one of the most highly disturbed areas since it is often filled with debris that is shifted back and forth along the shoreline with each changing tide.

Amaranthus cannabinus Cover Type

The *Amaranthus cannabinus* cover type is the most diffuse of the eight described. It occurs most often in the rocky shore areas, but may be found occasionally in backmarsh areas where the substrate is firm and gravelly (Figure 5). In rocky shore areas, this cover type extends from low-to-high tidal elevations, without an apparent zonal pattern.

Since the *Amaranthus cannabinus* cover type is comprised mainly of annuals (Table 3), abundance of the different species may change dramatically from year to year. Leck and Graveline (1979) found that annuals comprised seven of the ten most numerous species encountered in seed bank experiments conducted in the Hamilton freshwater-tidal marshes on the Delaware River near Trenton, New Jersey. They further reported that the riverbank, which had been scoured of all vegetation by ice and waves during the winter, produced dense growths of annuals during the summer. In the Merrimack River marsh, these rocky shore areas occur around two points that project into the river and are highly exposed to wind and waves (Figure 1). These extremely disturbed sites provide an open habitat for fast-growing annual species, with the rocky substrate affording the seeds protection from river and tidal currents. Backmarsh occurrence of the *Amaranthus cannabinus* cover type may be due to similar stony substrate in these areas.

Scirpus pungens Cover Type

Scirpus pungens dominates this cover type, intermixing only occasionally with patches of *Sagittaria graminea* (Table 3). *Scirpus pungens* forms a nearly monospecific zone in the low tide mud flats or occurs as scattered populations throughout the rocky shore areas (Figure 5). The mean cover value of other species associated with this cover type is less than 1 percent. When this small-stemmed perennial colonizes the lower limit of the low tide zone, it is submerged throughout most of its life. In the spring, the cold temperature of the mud and overlying river water delay shoot emergence until mid-May, a time when *Acorus calamus* is already beginning to flower. These plants remain somewhat stunted throughout most of the growing season and rarely produce flowers. Deschenes and Serodes (1985) found that *Scirpus pungens* (cited as *Scirpus americanus*) can withstand nearly 100 percent submersion under freshwater conditions, but its population size declines with increasing salinity.

Scirpus pungens matures relatively rapidly on the more elevated sections of rocky shore areas, however, and flowers in early June. This is one of the few rhizomatous plants that colonizes sloping surfaces and stony substrates of the Merrimack River shore areas. Hutchinson (1982) and Odum (1988) considered this species to be a pioneer, capable of quickly colonizing disturbed or bare areas by seed dispersal.

RARE PLANT DOCUMENTATION AND HABITAT DESCRIPTION

Three plant species listed by Sorrie (1987, 1990) as rare for the Commonwealth of Massachusetts occur in the Merrimack River marsh, including *Scirpus fluviatilis* (special concern), *Eriocaulon parkeri* (endangered) and *Bidens eatonii* (threatened). *Scirpus fluviatilis* has a wide distribution in fresh and tidal rivers across the United States. *Eriocaulon parkeri* and *Bidens eatonii* are confined to estuaries along the east coast (Crow and Hellquist, in press; Hellquist and Crow, 1982).

Six current sites have been documented for *Scirpus fluviatilis* in Massachusetts, including the Merrimack River freshwater tidal marsh (Sorrie, pers. comm.). These plants occur most often in the middle and backmarsh areas of the study site, rooted in a muddy, silty substrate and growing on the slightly elevated borders of islands in the marsh. Although large stands develop, most plants lack inflorescences, and reproduction is almost exclusively vegetative by means of an extensive rhizome system. Ferren and Schuyler (1980) reported similar observations of *S. fluviatilis* populations along the Delaware River. Leck et al. (1988) also reported that although this species occurred in their study area, it was not represented in the seed bank survey nor in the field as seedlings; they concluded that it rarely reproduces by seeds.

The second rare plant, *Eriocaulon parkeri*, is reported in only four locations in Massachusetts, including the Merrimack River marsh (Hellquist and Crow, 1982; Sorrie, pers. comm.). One small population was documented near the west end of the study site, and a second population, reported further down river, could not be located. Three boat docks have been built out from the riverbank, and a large section of shoreline clearing occurred during the two years of this study; this activity may account for disappearance of the second population.

The estuarine pipewort, *Eriocaulon parkeri,* grows in a gravelly, sandy substrate on the upper slope of the rocky shore in open sunlight. These plants are submerged for ca. 11 hours a day at high tide; the substrate in this area, although sandy, appears to remain continuously wet even at low tide. Associated vegetation is sparse, consisting of species such as *Scirpus smithii, Cyperus bipartitus, Isoetes echinospora, Equisetum fluviatile, Ludwigia palustris* and *Lindernia dubia.*

Although the range of *Eriocaulon parkeri* extends from Maine to South Carolina in estuaries along the coast, it is listed as rare and endangered for New England, Maine, Massachusetts and Connecticut (Crow et al., 1981; Hellquist and Crow, 1982). It is also rare in Delaware, New Jersey and New York (Tucker et al., 1979; Mitchell et al., 1980; Snyder and Vivian, 1981). Efforts should be made to protect the remaining populations of this rare plant and to preserve its habitat. The Merrimack River site is especially vulnerable due to recent and potential marsh destruction.

The third rare plant species, *Bidens eatonii,* was discovered by Alvah A. Eaton in 1902 from the "brackish shores of the Merrimack River in Newburyport, Massachusetts" (Fernald, 1903), just downstream from the study area. Since then, eight weakly defined varieties have been described, four of which have been documented from the Merrimack River estuary, var. *eatonii* Fern., var. *fallax* Fern., var. *illicita* Blake and var. *kennebecensis* Fern. (Fassett, 1925a; Sherff, 1937). In addition to these varieties, three other species of *Bidens* also occur in the study site, *B. cernua, B. frondosa* and *B. connata.*

Since *Bidens cernua* has simple sessile leaves and *B. frondosa* has compound petiolate leaves, both are easily recognized in the field. However, *Bidens eatonii* and *B. connata* are very similar and have simple petiolate leaves that frequently have basal lobes, and flowers that typically lack ray florets. In many cases it was impossible to distinguish between these two species in the field, especially since they were in the vegetative stage at the time of vegetation sampling. Therefore, these two species were grouped together in the abundance data for vegetation analysis.

Characters that have been considered important in distinguishing these two species include number, size and shape of terminal heads, as well as the surface features of achenes. *Bidens connata* has large (30–60 flowers) rounded heads, and *B. eatonii* has smaller (8–30 flowers) campanulate heads (Fassett, 1925a, 1925b). However, in examining many petiolate, simple-leaved specimens of *Bidens* in the Merrimack River marsh, a range of terminal head sizes and shapes was observed. Sorrie (1987) also found similar intermediate head characters in plants from a Threemile River population in Bristol Co., Massachusetts.

Achene surface features such as striations and tubercles also proved to be unsatisfactory as distinguishing characters. Both species have striate achenes (Fassett, 1925b) and the presence of tubercles, often used to distinguish *B. connata* from *B. eatonii,* was reported by Fernald (1908) to be an inconstant character.

Taxonomic identity could be further complicated in that all four species commonly grow together on tidal shores and in brackish marshes, and hybrids have been reported to occur between some of them. Fassett (1925a) described *B.* × *multiceps,* a hybrid of *B. connata* and *B. eatonii* from the Taunton River estuary of Massachusetts. Also, in a study of *Bidens connata* in Ontario, Crowe and Parker (1981) suggested that the Thunder Bay population, thought to be *B. connata,* may be an agamospermously-reproducing hybrid between *B. cernua* and *B. frondosa.* Both species occur in the same area and the supposed hybrid is intermediate in gross morphology between them. They further conclude that certain other taxa of *Bidens* which are poorly differentiated from *B. connata,* such as *B. eatonii,* "may likely be elements of a widespread agamic complex."

As a result of studies in the field and the examination of numerous herbarium specimens, there is good reason to question the taxonomy of *Bidens eatonii.* Whether *B. eatonii* is truly a distinct species, or whether it is a hybrid, or represents an ecotype or ecophene, remains to be seen. Clearly, additional studies are needed to resolve the taxonomic status of *Bidens eatonii* in order to determine accurately the taxonomic identity of these plants.

FLORA OF THE MERRIMACK RIVER FRESHWATER-TIDAL MARSH

The vascular flora of the Merrimack River freshwater tidal marsh consists of 88 species distributed among 66 genera in 38 families. Forty-five species are dicots and forty species are monocots. The best represented families are the Asteraceae, Cyperaceae and Poaceae.

Pteridophytes

ISOETACEAE

Isoetes echinospora Durieu Quillwort.
Occasional; at the east edge of Area 1 in the gravelly substrate in the high tide zone. *Caldwell 273, 488.*

EQUISETACEAE

Equisetum arvense L. Common Horsetail.
Occasional; throughout the marsh in the high tide zone. *Caldwell 407.*

Equisetum fluviatile L. Water Horsetail.
Common; in gravelly substrate in the high tide zone. *Caldwell 258, 426.*

Equisetum hyemale L. Scouring Rush.
Occasional; midmarsh with *Acorus calamus* at east end of study site.

Angiosperms

Dicotyledons

CABOMBACEAE

Cabomba caroliniana Gray Fanwort.
Occasional; in the Artichoke River. *Caldwell 449.*

CERATOPHYLLACEAE

Ceratophyllum demersum L. Coontail.
Occasional; in the Artichoke River. *Caldwell 448.*

RANUNCULACEAE

Caltha palustris L. Marsh-marigold.
Common; in the high tide zone throughout the marsh. *Caldwell 210.*

Ranunculus repens L. Creeping Buttercup.
Common; in gravelly areas between deep marshes in high tide zone. *Caldwell 203, 235.*

Thalictrum pubescens Pursh Tall Meadow-rue.
Common; in the backmarsh near the woods. *Caldwell 212.*

URTICACEAE

Pilea pumila (L.) Gray Clearweed.

Common; in the backmarsh near the high tide zone. *Caldwell 305, 380, 501.*

AMARANTHACEAE

Amaranthus cannabinus (L.) Sauer (= *Acnida cannabina* L.) Water-hemp.

Abundant; throughout the marsh, especially in the gravelly areas between the deep marshes. *Caldwell 244, 283, 284, 484.*

CARYOPHYLLACEAE

Sagina procumbens L. Pearlwort.

Occasional; in wet depressions in the high tide zone. *Caldwell 229.*

POLYGONACEAE

Polygonum arifolium L. Tearthumb.

Common; in the backmarsh. *Caldwell 302.*

Polygonum cuspidatum Sieb. & Zucc. Japanese Knotweed.

Common; in the backmarsh near edge of the woods. *Caldwell 268.*

Polygonum punctatum Ell. Water Smartweed.

Abundant; throughout the marsh. *Caldwell 255, 482.*

Rumex crispus L. Yellow Dock.

Common; at the edge of the marsh in the high tide zone. *Caldwell 230, 251.*

ELATINACEAE

Elatine americana (Pursh) Arn. (= *E. triandra* var. *americana* (Pursh) Fassett) Waterwort.

Abundant; growing on the mud throughout marsh. *Caldwell 291, 476, 487, 504.*

BRASSICACEAE

Cardamine pensylvanica Muhl. *ex* Willd. Pennsylvania Bitter Cress.

Occasional; at the edge of marsh, especially in gravelly areas between the deep marshes. *Caldwell 404, 423.*

PRIMULACEAE

Lysimachia ciliata L.

Occasional; at the edge of the marsh near woods. *Caldwell 468.*

Lysimachia lanceolata Walt.

Occasional; in the backmarsh. *Caldwell 248, 261.*

Lysimachia terrestris (L.) BSP. Swamp Candles.

Abundant; throughout the marsh near high tide zone. *Caldwell 454, 471.*

ROSACEAE

Potentilla norvegica L.

Uncommon; at the edge of the marsh near woods. *Caldwell 452.*

Sanguisorba canadensis L. American Burnet.

Uncommon; in open areas between the deep marshes near the high tide zone. *Caldwell 276, 511.*

FABACEAE

Amorpha fruticosa L. False Indigo.

Occasional; in the high tide zone between Area 2 and Area 3. *Caldwell 417, 520.*

LYTHRACEAE

Lythrum salicaria L. Purple Loosestrife.

Occasional; in the backmarsh. *Caldwell 239, 445.*

ONAGRACEAE

Ludwigia palustris (L.) Ell. Water-purslane.

Common; throughout the backmarsh in muddy substrate. *Caldwell 310, 381, 475.*

BALSAMINACEAE

Impatiens capensis Meerb. Spotted Touch-me-not.

Abundant; throughout the elevated areas and the backmarsh. *Caldwell 306.*

APIACEAE

Cicuta bulbifera L. Bulb-bearing Water-hemlock.

Occasional; in the backmarsh in Area 1. *Caldwell 345, 522.*

Cicuta maculata L. Water-hemlock.
Common; in the backmarsh. *Caldwell 451, 436.*

Sium suave Walt. Water-parsnip.
Abundant; throughout the marsh, especially in the stony areas between the deep marshes. *Caldwell 240, 322, 474.*

APOCYNACEAE

Apocynum cannabinum L. Indian-hemp.
Occasional; in the high tide zone between Area 2 and Area 3. *Caldwell 440, 505.*

LAMIACEAE

Lycopus americanus Muhl. Water-horehound.
Common; in the backmarsh. *Caldwell 242, 323, 379, 495.*

Mentha arvensis L. Water Mint.
Common; throughout the marsh in the high tide zone. *Caldwell 242, 462.*

Physostegia leptophylla Small (= *P. arboriginorum* Fern.)
Occasional; in the shade near the high tide zone between Area 2 and Area 3. *Caldwell 512.*

Scutellaria lateriflora L. Skullcap.
Occasional; in the backmarsh near the edge of the woods. *Caldwell 378, 499.*

CALLITRICHACEAE

Callitriche verna L. (= *C. palustris* L.) Water-starwort.
Occasional; along the edge of the Indian River and the west side of the island near the Artichoke River. *Caldwell 228, 432.*

SCROPHULARIACEAE

Chelone glabra L. Turtlehead.
Common; in the backmarsh and the edge of the island near the Artichoke River. *Caldwell 329, 336, 509.*

Lindernia dubia (L.) Pennell False Pimpernel.
Common; in the high tide zone at the edges of the deep marshes. *Caldwell 262, 480.*

Mimulus ringens L. Square-stem Monkey-flower.
Common; throughout the marsh in the high tide zone. *Caldwell 245, 441, 469, 521.*

RUBIACEAE

Galium palustre L. Bedstraw.

Occasional; in the muddy areas of the backmarsh in the high tide zone. *Caldwell 217, 224, 500.*

ASTERACEAE

Aster novi-belgii L. New York Aster.

Abundant; throughout the marsh in the high tide zone at the edge of the woods. *Caldwell 338, 516, 519.*

Bidens cernua L. Beggar's-ticks.

Abundant; throughout the midmarsh but more frequently in the backmarsh. *Caldwell 281, 303, 309, 328, 481.*

Bidens connata Muhl. *ex* Willd.

Common; throughout the marsh. *Caldwell 355, 358.*

Bidens eatonii Fern.

Common; in the gravelly and elevated areas of the marsh. *Caldwell 506, 507, 510, 525.*

Bidens frondosa L.

Occasional; in the backmarsh in the high tide zone. *Caldwell 335, 340, 524.*

Eupatorium dubium Willd. *ex* Poir. Joe-pye Weed.

Common; at the edge of the marsh in the high tide zone. *Caldwell 274, 496.*

Eupatorium perfoliatum L. Boneset.

Abundant; in the elevated areas and the backmarsh in the high tide zone. *Caldwell 437, 465, 497.*

Solidago sempervirens L. Seaside Goldenrod.

Common; between the deep marshes in the high tide zone. *Caldwell 325, 517, 518.*

Tussilago farfara L. Coltsfoot.

Uncommon; between Area 2 and Area 3 in the high tide zone. *Caldwell 405.*

Monocotyledons

ALISMATACEAE

Alisma subcordatum Raf. (= *A. plantago-aquatica* var. *parviflorum* (Pursh) Torr.) Water-plantain.

Uncommon; in the backmarsh of Area 1. *Caldwell 271, 478.*

Alisma triviale Pursh (= *A. plantago-aquatica* var. *americana* Schultes & Schultes) Water-plantain.
Uncommon; in the backmarsh of Area 3. *Caldwell 494.*

Sagittaria graminea Michx. var. *graminea* (*S. eatoni* J. G. Sm.)
Abundant; throughout the marsh in muddy silty substrate. Occurring as sterile rosettes in the low tide zone. *Caldwell 232, 241, 254, 261, 279, 280, 429, 439.*

Sagittaria latifolia Willd. Arrowhead.
Abundant; throughout the middle and backmarsh in muddy substrate. *Caldwell 264, 278, 331, 332, 477, 493.*

HYDROCHARITACEAE

Elodea nuttallii (Planch.) St. John Waterweed.
Abundant; throughout the marsh in muddy substrate or in large patches in open areas in the low tide zone. *Caldwell 222, 257, 294, 433.*

Vallisneria americana Michx. Tape-grass.
Common; washed up on shore throughout the marsh. *Caldwell 277, 498.*

POTAMOGETONACEAE

Potamogeton crispus L. Curly-leaved Pondweed.
Occasional; rooted in the mud in the low tide zone or washed up on shore. *Caldwell 221, 479.*

Potamogeton nodosus Poir.
Occasional; in the muddy substrate of the high tide zone; plants vegetative only. *Caldwell 218, 333, 412, 527.*

Potamogeton perfoliatus L. Clasping-leaved Pondweed.
Occasional; rooted in the mud in the low tide zone and at the edges of the Artichoke River. *Caldwell 219, 420, 450.*

Potamogeton robbinsii Oakes Robbins' Pondweed.
Uncommon; in the Artichoke River. *Caldwell 447.*

ARACEAE

Acorus calamus L. Sweet-flag.
Abundant; occurs as a large zone mid-marsh with scattered populations near the edges. *Caldwell 204, 402, 411.*

Peltandra virginica (L.) Schott & Endl. Arrow-arum.
Common; in the deep mud of backmarsh. *Caldwell 424, 434.*

LEMNACEAE

Wolffia columbiana Karst. Water-meal.
Uncommon; washed up on shore. *Caldwell 313.*

COMMELINACEAE

Commelina communis L. Asiatic Dayflower.
Occasional; in the high tide zone between Area 2 and Area 3. *Caldwell 459.*

ERIOCAULACEAE

Eriocaulon parkeri Robins. Pipewort.
Occasional; at the east edge of Area 1 in gravelly substrate in the high tide zone. *Caldwell 259, 272, 319, 492.*

JUNCACEAE

Juncus acuminatus Michx.
Occasional; in the gravelly substrate between the deep marshes. *Caldwell 234, 253, 446, 455.*

CYPERACEAE

Carex hormathodes Fern.
Uncommon; in the high tide zone at the east edge of Area 1. *Caldwell 427.*

Carex paleacea Wahlenb.
Occasional; in the gravelly substrate between the deep marshes and elevated backmarsh. *Caldwell 205, 413.*

Carex stipata Muhl. *ex* Willd.
Uncommon; in the high tide zone at east edge of Area 1. *Caldwell 421.*

Cyperus bipartitus Torr. (= *C. rivularis* Kunth)
Occasional; in the gravelly substrate in the high tide zone. *Caldwell 491.*

Cyperus esculentus L. Yellow Nut-grass.
Occasional; in the gravelly substrate in the open areas. *Caldwell 292.*

Dulichium arundinaceum (L.) Britt. Three-way Sedge.
Frequent; in large clumps in the gravelly areas and in the backmarsh. *Caldwell 456, 508.*

Eleocharis smallii Britt. Spike Rush.
Frequent; in the gravelly areas and the elevated borders of the islands. *Caldwell 211, 247, 287, 408, 425, 457.*

Scirpus fluviatilis (Torr.) Gray River Bulrush.
Frequent; in the midmarsh and elevated borders, particularly around the islands. *Caldwell 285, 312, 400, 401, 430, 443, 503.*

Scirpus pungens Vahl. (*S. americanus* of American authors, misapplied to this taxon) Three-square Bulrush.
Abundant; throughout the marsh in the low tide zone and the gravelly areas. *Caldwell 214, 233, 249, 270, 286, 442.*

Scirpus smithii Gray
Uncommon; in the gravelly substrate with *Eriocaulon parkeri* at the east end of Area 1 near the high tide zone. *Caldwell 490.*

Scirpus tabernaemontanii K. C. Gmel. (= *S. validus* Vahl.) Great Soft-stem Bulrush.
Abundant; midmarsh in the silty muddy substrate. *Caldwell 213, 256, 431.*

POACEAE

Agrostis stolonifera L. var. *stolonifera* (= *A. stolonifera* var. *major* (Gaud.) Farw.; *A. alba* var. *stolonifera* (L.) Sm.) Redtop.
Occasional; at the edge of the marsh in the high tide zone. *Caldwell 470.*

Calamagrostis canadensis (Michx.) Beauv. Bluejoint.
Frequent; at the edge of the marsh in the high tide zone. *Caldwell 227, 428.*

Dactylis glomerata L. Orchard Grass.
Uncommon; at the edge of marsh in the high tide zone near the woods. *Caldwell 206.*

Panicum dichotomiflorum Michx. var. *geniculatum* (Wood.) Fern.
Uncommon; in a gravelly area of the river bank that was cleared by landowner. *Caldwell 344.*

Phalaris arundinacea L. Reed Canary Grass.
Occasional; in the high tide zone throughout the marsh. *Caldwell 208, 414.*

Spartina alterniflora Loisel. Saltwater Cord Grass.
Frequent; in large clumps in the silty substrate near the low tide zone. *Caldwell 485, 506.*

Spartina pectinata Link Freshwater Cord Grass.
Frequent; in the gravelly substrate in the high tide zone. *Caldwell 236, 250, 444.*

Zizania aquatica L. var. *aquatica* Southern Wild-rice.
Abundant; scattered throughout the marsh, but especially abundant in the deep mud of the backmarsh. *Caldwell 260, 267, 486.*

SPARGANIACEAE

Sparganium eurycarpum Engelm. Large-fruited Bur-reed.
Occasional; in the backmarsh and bordering the Indian River. *Caldwell 269, 304, 418.*

TYPHACEAE

Typha angustifolia L. Narrowleaf Cattail.
Occasional; in the elevated areas bordering the island near the Indian River. *Caldwell 223.*

PONTEDERIACEAE

Pontederia cordata L. Pickerel-weed.
Abundant; in the deep mud of the backmarsh and occasionally the midmarsh. *Caldwell 238, 467.*

IRIDACEAE

Iris pseudacorus L. Yellow Iris.
Occasional; in the high tide zone and the elevated areas bordering the islands. *Caldwell 201, 226.*

Iris versicolor L. Blue Flag.
Occasional; in the high tide zone between the deep marshes. *Caldwell 202.*

CONCLUSION

Several biotic and abiotic factors influence the composition and distribution of vegetation in a freshwater tidal marsh. Three environmental parameters that may be related to plant community structure were explored, including salinity, organic content of the soil, and water level fluctuation.

Although salinity is a hydrological component of a freshwater tidal marsh, levels of less than 5‰ measured at the study site were probably too low to be a major influence on the structure of plant cover types. Also, the fact that salinity occurred near the end of the growing season seemed to further negate its influence on community structure.

Soil organic content measurements indicate that a large percentage of the marsh, encompassing many cover types, contains mineral soil with a low level of organic matter. Although species diversity is the highest in backmarsh cover types where soil organic content is highest, more sampling needs to be done to substantiate any conclusions.

On the other hand, duration of inundation at the plant/soil interface appears to be an important factor in structuring marsh cover types. Species diversity is lowest in cover types such as those dominated by *Spartina alterniflora* and *Scirpus pungens*, where duration of flooding is the longest (16 hr./day). Few emergent species can tolerate this extensive period of inundation. Mid- to backmarsh cover types such as those dominated by *Acorus calamus* and *Zizania aquatica* have more diversity. However, this analysis does not hold true for rocky shore areas where presumably the high degree of disturbance is an overriding influence on vegetation patterns.

Two other important factors contributing to plant community structure in the Merrimack River marsh that should be mentioned here are plant growth forms and physical disturbance by ice floes. The most successful plants in this fluctuating environment are either annuals or strongly rhizomatous perennials. A proliferation of rhizomes allows these plants to take hold in areas of constant sediment deposition and erosion, while storing nutrients for early emergence and rapid growth. The seeds of annuals, in contrast, find protection in the microrelief of the marsh surface and rocky shoreline.

The Merrimack River is a relatively large and rapidly moving river that partially freezes during the winter. Therefore, ice floes also have a major impact on the vegetation of the marsh and rocky shoreline. Plants along the banks are sheared by ice scouring. Additionally, sediments containing seeds and rhizomes are entrapped and transported by ice chunks drifting up and downstream on tidal and river currents, often being deposited along the river's edge or carried out to sea.

Freshwater tidal marshes are the least studied wetlands in the U.S. (Odum et al., 1984). This environment is dynamic, with many distinctive plant species. Research in many more freshwater tidal rivers is surely needed to better understand this unique habitat.

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